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HUMAN PERFORMANCE FACTORS IN AVIATION

by

Diane A. Klassen

for

Transportation Development Centre
Policy and Coordination Group

December 1989

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Un sommaire en français de ce rapport est inclus avant la table des matières.

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Using a systems model, this report discusses human factors and man-machine-environment concepts especially as they relate to flight safety. It identifies salient operational issues and makes recommendations for further research.

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16. Résumé

À l'aide d'un modèle de système, l'auteur explique la notion d'interface pilote-machine-environnement, dont il établit les rapports avec la sécurité dans un poste de pilotage. Le rapport souligne les thèmes prédominants dans ce domaine et formule des recommandations concernant l'avenir de cette recherche.

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SUMMARY

This report emphasizes the importance of human factors in aviation, and the need for the system to recognize human performance capabilities and to accommodate human limitations. Human factors is a multi-disciplinary applied technology concerned with people in their working and living environments and with their relationships with machines, procedures and other people in the system. This man-machine-environment concept is illustrated using a systems model called SHEL.

Following a review of current accident statistics in Canada, the report discusses the myth of "pilot error" and describes two error taxonomies. The rationale for a "human-centred" approach to cockpit and air traffic control automation is presented. The importance of the socioeconomic environment is described with respect to economic regulatory reform and cabin safety. The need for training in decision making and "crew" resource management to improve judgement and interpersonal relations is the last interface topic. Specific recommendations are made to develop human factors and decision making training programs and to improve cabin safety and passenger awareness. Long term initiatives are suggested with respect to information transfer problems, data collection methods, pilot and controller selection and training criteria, unique Canadian operations and shift work schedules.

Human performance factors account for over 80% of the system failures. To improve the safety of the system it is necessary to minimize the opportunities for error, reduce the consequences of error and adapt the system to manage the risk.

SOMMAIRE

Ce rapport souligne l'importance qui doit être donnée aux facteurs ergonomiques, notamment dans le domaine de l'aviation, et la nécessité que tout système puisse s'adapter tant aux aptitudes des opérateurs humains qu'à leurs limites. L'ergonomie, discipline multidisciplinaire, est une manière d'envisager le travail et les activités ordinaires de la vie dans un environnement donné; elle explique les relations des humains avec les machines dont ils se servent, les procédures qu'ils mettent en oeuvre et même les rapports des humains entre eux à l'intérieur du système envisagé. Pour illustrer le concept de cette interface homme-machine-environnement, un modèle baptisé SHEL a été réalisé.

Après un tour d'horizon des statistiques sur les accidents au Canada, le rapport s'attaque au mythe de l'"erreur humaine" dont il décrit deux taxinomies, et explique le bien-fondé d'une approche plus "humaine" de l'automatisation tant des postes de pilotage que du contrôle de la circulation aérienne. Il souligne l'importance des facteurs socio-économiques en jeu à la lumière d'une réforme des règles économiques et des paramètres régissant la sécurité dans un poste de pilotage. Enfin, il insiste sur l'importance d'une formation en matière de prises de décision et de maîtrise des ressources animant un poste de pilotage, comme moyen d'éclairer les jugements et d'améliorer les rapports qui doivent exister entre les membres d'un même équipage. Il formule des recommandations concrètes pour l'élaboration de programmes ayant le triple but de donner aux équipages une formation permettant de maîtriser le processus de prise de décisions compte tenu des facteurs ergonomiques en jeu, d'améliorer la sécurité dans le poste de pilotage et de sensibiliser le public voyageur à toutes ces questions. Il propose des actions de longue haleine en vue de régler les problèmes liés à la saisie et au transfert de l'information, aux critères de sélection des pilotes et des contrôleurs et à leur formation, à la répartition du travail et au contexte des opérations aériennes au Canada.

Le facteur humain entre dans plus de 80 p. 100 des défaillances constatées dans un système. Pour remédier à cet état de choses, il faut éliminer le plus possible les possibilités d'erreur, minimiser les conséquences d'une faute et donner au système des fonctions de gestion permettant de réduire les risques au minimum.

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1. INTRODUCTION

1.1 PURPOSE, SCOPE, & OBJECTIVES

This paper concludes my project on human factors under the visiting research program for the Transportation Development Centre.

I have attempted to emphasize and illustrate the importance of human factors. The system needs to recognize human performance capabilities, and accommodate human limitations, in order to prevent and reduce both the occurrence and the consequence of failures. The system in this case is aviation, but the concepts apply to any mode of transportation, and for that matter, to any environment. Over 20 years ago, Drew (1967) estimated that 80% to 90% of all accidents resulted from human performance factors.

In non-theoretical language, this report introduces the man-machine-environment concept using a systems model, identifies salient operational issues which influence flight safety, and makes recommendations for further evaluation, research and development. It was not possible in such a short period to complete a comprehensive study nor to compile an exhaustive inventory of reference material.

1.2 BACKGROUND

Human factors is a complex multi-disciplinary applied technology, concerned with people in their working and living environments and with their relationships with machines, procedures and other people in the system. The multi-disciplinary nature is reflected by the constituent subjects: engineering, psychology/sociology, physiology, medicine, education and law. Edwards (1985) stated:

> "Human factors (or ergonomics) may be defined as the technology concerned to optimize the relationships between people and their activities by the systematic application of the human sciences, integrated within the framework of system engineering."

This expanded definition goes beyond the European definition of ergonomics - the study of man in his working environment. It includes people and their activities - at home, work and leisure -and their interpersonal communications and group behaviour. Optimization of relationships means both individual well-being (e.g. job satisfaction) and effective system performance (e.g. safety and efficiency).

For 50 years the applied physical sciences have concentrated on machine technology. Only recently have the applied human sciences directed serious attention to methods of preventing and reducing human performance failures by adapting designs, systems and operating procedures to human capabilities and limitations. Man-machine-environment mismatches arise when insufficient attention is given to human characteristics and skills.

1.3 HISTORICAL OVERVIEW

For nearly sixty years, it has been general known by those in the field that three out of four aircraft accidents result from human failure and error. During World War II and continuing for the next 30 years, human factors research was sponsored mostly by the military, notably in the UK and the USA. Applications within aviation consisted mainly of psychological testing for aircrew selection and training; studying the effects of sleep loss, fatigue and stress; and research into cockpit design, layout, displays and controls. For example, experiments conducted in a simulator called the Cambridge Cockpit led to the conclusion that system designers had to match the machine to the man not the other way around - perhaps the first tenet of human engineering.

By the 1970s a fundamental knowledge gap was recognized in civil aviation. In 1975 the International Air Transport Association (IATA) cautioned that lack of appreciation for the application of human factors to aviation may bring about a major disaster. Less than 2 years later the Tenerife accident occurred - then the worst in history and the first to be attributed solely to human errors. Shortly after, KLM Royal Dutch Airlines developed and implemented KHUFAC (KLM Human Factors Awareness Course), the first human factors awareness program.

2. AVIATION SAFETY IN CANADA

The main sources of statistical information are the agencies responsible for accident investigation and analysis such as the Canadian Aviation Safety Board (CASB) and in the USA, the National Transportation Safety Board (NTSB). This data is collected to meet operational mandates or fulfil international agreements, and does not contain normative, non-accident information, such as human errors without reportable consequence. However it does provide some significant insights.

As of the end of 1988, over 27,000 civil aircraft were registered in Canada and more than 74,000 pilots (including student pilots) were licensed (Transport Canada records). During 1988, Canadian registered aircraft were involved in 497 accidents which included 49 fatal accidents and 94 fatalities. An additional 25 foreign-registered aircraft were involved in accidents in Canada of which 4 were fatal involving 4 fatalities. This increase of about 5% over 1987 figures was accompanied by an estimated 7% increase in the hours flown to yield a small decrease in the accident rate: 13.4 accidents per 100,000 hours flown. The Canadian accident rate has tended to decline since the early 1970s while the proportion of accidents resulting in fatalities has remained steady at approximately 12% for over a decade. Not surprisingly, unit toll carriers accounted for 1.6%, charter operations 25.7% and private operators 50.3% of the total. The balance involved state, flying club and specialty aircraft.

A comparison of accident rates, based on number of hours flown, showed a decrease in the commercial accident rate while hours flown had increased; and conversely, the number of hours flown by private operators had decreased more rapidly than the number of accidents (all statistics taken from the CASB Annual Report 1988).

In their 1986 Annual Report, the CASB published the inter-related human-machine-environment contributing factors for two types of occurrences. Human performance factors were identified in 77% of engine failures and 92% of control problems in the air. Overall, since 1980, human factors have been identified in more than 80% of accidents investigated by the CASB and previously by the Aviation Safety Bureau of Transport Canada.

In 1989, the CASB conducted a special investigation into air traffic services (ATS), the first of its kind in Canada. From the 710 recorded occurrences of "loss of safe separation" in Canadian controlled airspace since 1985 (including the Gander oceanic airspace), 217 cases were selected for detailed examination. All occurrences involving an aircraft over 5700 kilograms and an aircraft in IFR flight (which could be the same aircraft) were examined. Interviews were conducted with a total of 80 air traffic controllers, supervisors and managers at Toronto, Vancouver, Montreal and Gander. Of these 217 occurrences, approximately 90% involved human factors problems within ATS of which 50% were categorized as inattention: i.e. forgetting, failing to maintain constant vigilance, and distraction. Other identified human factors problems were: communication breakdown (information transfer problems), planning, judgement,and shift cycle fatigue/stress (source CASB personnel).

Also in 1989, the CASB analyzed all accidents between 1976 and 1985 in which a Canadian pilot either took-off VFR or continued VFR flight into adverse weather - a total of 333 accidents. These accidents made up 6% of all accidents during the same period, but 23% of fatal accidents and 26% of fatalities. Two patterns were identified: "controlled flight into terrain" and loss of control. Controlled flight into terrain accidents tended to result from "scud running", a common practice amongst bush pilots. Pilots who lost control before impact tended to be less experienced with no IFR training (source CASB personnel). It is expected that both of these reports, when published, will make a number of safety recommendations to Transport Canada.

What is this telling us? It only confirms what is already known. The human operator is the weakest link. Taken together, mechanical failures and physiological factors account for only a small percentage of accidents. Traditional accident prevention techniques, such as reconstructing aircraft components, are important. Equally important to improve the safety of the system, is the application of human factors expertise. At present, there are no personnel dedicated to general human factors work within the CASB (with 293 allocated person years), or within Transport Canada Aviation Group.

3. "PILOT ERROR" AND ERROR TAXONOMIES

The term "pilot error" is both a misnomer and a myth. There is nothing innately unique about pilots that causes error, nor is the nature of error different than that of other occupations. We don't however, refer to "mechanic error", "surgeon error", or "chef error". Pilot error has been used by accident investigators and design engineers as a catch-all category which explains nothing except where the buck stops. Errors result from man-task mismatch situations. Given the integrated nature of human behaviour,

> "... solutions to the error problem must be developed in ... a 'systems context'... [T]he pilots, the machinery, or any of the other human actors ... are interdependent, and changes in any one eventually are reflected in the others." (Nagel, 1988, p 299).

Research is needed to identify all the factors interacting in the system, including those not resulting in incidents or accidents, i.e. what may go wrong (behavioral), how it may go wrong (contextual), and why it may go wrong (conceptual).

Two premises must be accepted. Neither human pilots nor human errors will ever be eliminated. Systems cannot be automated sufficiently to fulfil all the roles currently filled by pilots, and human beings by their very nature are fallible. To improve the safety of the system, it is necessary to minimize the occurrence of errors, reduce the consequences of the remaining errors (Hawkins, 1987) and adapt the overall system to manage the risk safely. Reducing the incidence and severity of human error involves three approaches (Nagel, 1988): avoid errors by the careful and informed design of controls, displays, operating procedures, etc. (since design decisions are also decisions about the nature of human error which will occur); reduce errors through selection and training; and design error-tolerant systems. For example, automated monitoring systems can warn the human crew of errors as they are made; and redundancies such as multiple crew significantly reduce the probability that any given error will lead to an accident.

3.1 ERROR TAXONOMIES

Numerous taxonomies or classifications appear in the literature. To be useful in either a theoretical or a practical context, a taxonomy must simplify the data while simultaneously allowing for a multiplicity of possible causal interactions. Two examples are given by way of illustration only, without theoretical discussion. The first error taxonomy appears in Hawkins (1987):

i. Design-induced error
Also called situation-caused error, this is exemplified by Murphy's Law - if hardware is designed so that it can be operated wrongly, sooner or later it will be, e.g. flap and gear controls of similar shape located in close proximity.

ii. Systems-induced error
The software version of the preceding, this refers to the non-physical aspects of the system in which the sources of errors are often less tangible, e.g. symbology of the Head-Up Display (HUD).

iii. Operator-induced error
Also called human caused error, this refers to inadequate performance (behaviour) on the part of the human resulting , for example, from lack of skill, motivation or poor judgement.

Jensen and Benel (1977) developed the second example based on their analysis all general aviation accidents from 1970-1974.

i. Procedural activities
These were errors in operating aircraft systems or equipment, e.g. selecting wrong radio frequency. This type only accounted for 9% of nonfatal and 5% of fatal accidents.

ii. Perceptual-motor activities
These were errors in handling aircraft controls, e.g. flaring late on landing. This type accounted for 56% of the nonfatal and 44% of the fatal accidents.

iii. Decisional activities
These were errors in thinking or cognitive errors, e.g. continuing flight into adverse weather. This type accounted for 35% of the nonfatal and 52% of the fatal accidents. In a comprehensive report to the FAA, the authors recommended that judgement training materials be developed and scientifically tested. The follow-on is discussed in the next chapter under decision-making training.

4. MAN - MACHINE - ENVIRONMENT INTERFACES

4.1 SHEL

SHEL is a popular model developed by Elwyn Edwards (1972, 1988) to describe man's relationships with other people, machines and the environment from a systems context (see Appendix A).

S - Software

Software refers to the non-tangibles such as rules, regulations, laws, orders, procedures, customs, practices, habits, symbology, computer programs and the layout of manuals and checklists. Problems resulting from the impact of these non-physical aspects of the system are frequently more difficult to resolve.

H - Hardware

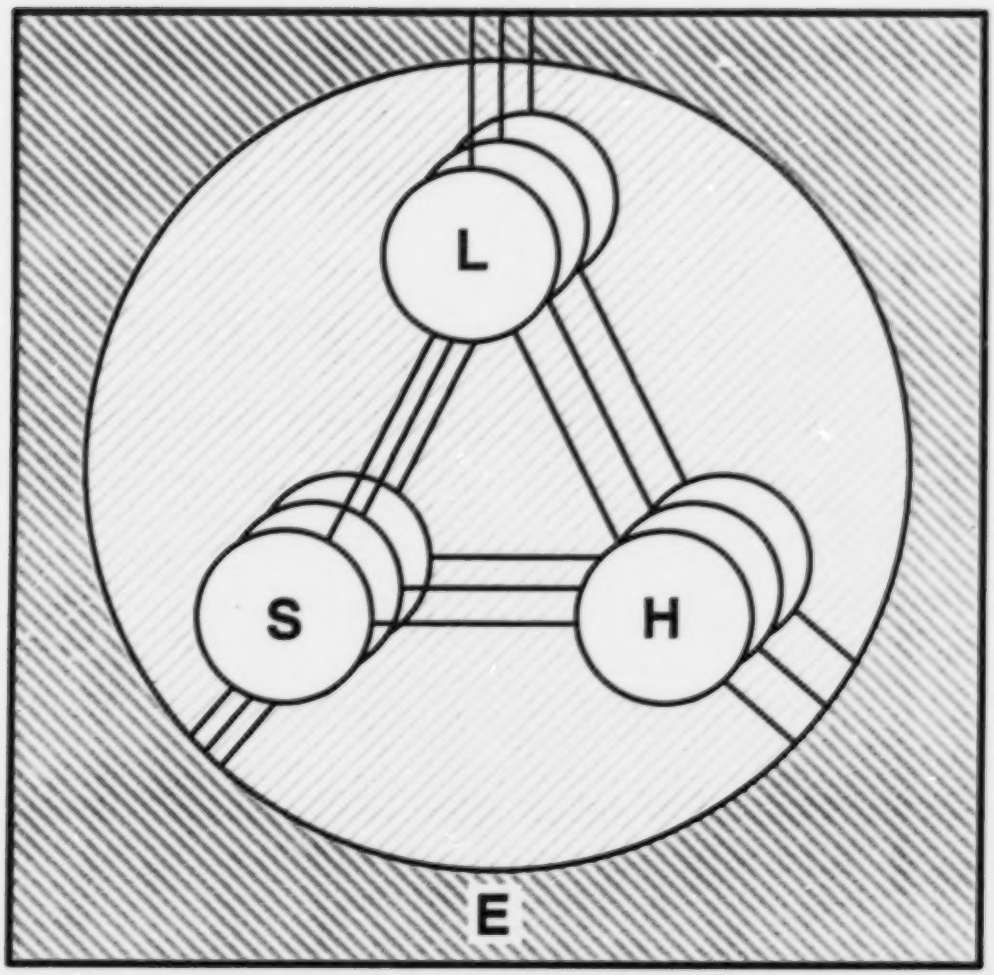
Hardware refers to tangible physical property such as buildings, vehicles, equipment and materials. In an aircraft, the nature of the man-machine interface is determined by factors such as displays and controls (the primary means by which humans interact with machines), alerting and warning systems, motor workload, cockpit visibility, and personal comfort.

Given the natural human characteristic of adapting to the machine, a potentially dangerous mismatch may only become apparent when it finally leads to disaster. Recognition of the importance of the human operator in the functioning of the man-machine component has led to the inclusion of words like "user friendly" in our everyday vocabulary.

E - Environment

Environment is made up of physical (both internal and external), economic, political and social factors and includes all those factors over which the systems designers have no control. Initially, resolving problems such as noise, temperature, air pressure and G forces, was accomplished by adapting man to the environment (e.g. helmets, flight suits, goggles, oxygen masks and anti-G suits). More recently, recognition of the importance of adapting the machine to the humans led to pressurization, air conditioning, temperature control and soundproofing.

At the present time, certain aspects of the socioeconomic environment are having a considerable effect on the system. Of interest are regulatory and legal factors such as economic regulatory reform (ERR), company organizational structure and economic well-being, employer-employee



SHEL Model – Elwyn Edwards

relations and unions, employee family relationships, peer group attitudes (degree of professionalism), and the declining experience base of professional pilots at all levels in the system.

L - Liveware

The most important component, liveware, refers to man himself and his relationships with other human beings. This interface encompasses factors such as aviation physiology and psychology, verbal and non-verbal communication, problem solving and decision making, and small group dynamics (e.g. crew management).

4.2 SOME FACTORS AFFECTING HUMAN PERFORMANCE

The use of a model, such as SHEL, is primarily to promote understanding. In the real world, the factors affecting human performance overlap from one component to another. The balance of this chapter is devoted to the following topics: some potential effects of automation on human performance; some implications with respect to the socioeconomic environment; and the issue of decision making training for pilots. For the sake of continuity, general recommendations are included with the specific topic.

Human Performance and Automation

In theory, automated systems enhance safety and efficiency. They reduce flight time, navigate more precisely, operate aircraft engines more efficiently, (all of which benefit the environment in fuel saved and less pollution), and allow more aircraft to be handled without increasing the number of controllers or the workload. In other words, automation is increasing the capability of both the aircraft and the air traffic control system.

Phrases such as "pilot's associate" and "electronic crew member" are indicative of available technology in the field of intelligent computer systems ("artificial intelligence"). Human factors specialists, echoing the concerns of pilots and others in aviation, are warning of the dangers of over-automation - technology for the sake of technology. They are pointing first to the need to resolve problems created by the current technology (displays driven by computer graphic systems or "glass cockpits"); and second to adopt a "human-centred" approach in future systems designs (Wiener, 1988; Taylor, 1989). The potential hazards resulting from highly automated systems and affecting both flight crews and air traffic controllers have been identified by several authors (e.g. Wiener, 1988, 1989; Hopkin, 1989). In both cases the emerging issues are identical.

One of the most serious human factors problems is loss of "situational awareness". For the pilot, this means: knowing

> "...where the aircraft is geographically, what its current performance state is, its altitude, power setting, configuration, and relationship to other aircraft.... Information...is obtained visually, through the windows of the aircraft and from instruments, aurally from other crew members...and from air traffic controllers..., and through the vestibular senses....all of...[which] are subject to error." (Nagel, 1988, p 275).

Wiener states the question is not what automation can do but what it should do. Glass cockpits reduce workload where you don't want it reduced, (e.g. on long haul flights resulting in "underload", boredom, complacency and loss of situational awareness); and increase it where you don't want it increased (e.g. on arrival in a busy terminal area resulting in overload and increased "head down" time re-programming). In short, "...to discover if an aid is mismatched to human needs ... ascertain if it is most useful when least needed and least useful when most needed" (Hopkin, 1989).

With automation, the role of the human operator is increasingly that of monitor and supervisor even though it is widely accepted that humans do not perform this function reliably. Both the pilot and the controller perform fewer manual tasks (e.g. writing flight strips) which help maintain situational awareness, and more cognitive activities (such as planning and decision-making). These cognitive tasks are also compressed into peak activity periods, placing increased demands on memory and attention.

All of this leads to a "catch 22" situation. The human operator must stay in the "control loop" - that is, must maintain "situational awareness"; must be able to detect failures and diagnose faults in automated systems; and must be able to take control. Both the pilot and the air traffic controller face problems of boredom and complacency during quiet periods, which leads to loss of situational awareness and corresponding inability to detect and identify failures. If able to recognize a failure, the loss of manual skill proficiency, or unwillingness to over-ride the automatic system (perhaps due to faith in its technological reliability), may prevent human recovery.

In addition, automated aids are usually operated by individuals, providing fewer opportunities for team work and personal interactions. As a result, technical skills and professional standards and norms may not be as well assimilated because the novice has not absorbed these through collaborative on-the-job training. The overall result could be a loss of professional pride and ultimately, job satisfaction (Hopkin, 1988).

A balance is needed, in terms of sustainable development. System designs should consider the roles of the people and maximize human capabilities such as innovation, flexibility, motivation, and technical skills; while at the same time circumventing human limitations such as monitoring. Tasks can be designed to require sufficient interpersonal interaction to perpetuate professional norms. Sufficient manual (or routine) tasks can be included to aid memory, entrench understanding and maintain situational awareness.

Some Effects of Economic Regulatory Reform

Freedom to compete and to establish schedules based largely on customer demands has led to greater numbers of aircraft, more airlines operating at major centres, the development of a "hub and spoke" system and peak activity periods. In the drive to stay competitive and the struggle to survive, there is increased pressure on companies to cut indirect operating expenses such as safety and maintenance. A vivid description of the safety implications of de-regulation in the United States is given by John Nance in his book Blind Trust (1986). Regulatory agencies in Canada, while presently experiencing the same pressures, are being forced to operate with reduced resources because of government deficit reduction measures.

With increased aviation activity there is increased vertical mobility for experienced personnel. This has resulted in a declining experience base for pilots at all levels in the hierarchy. North American airlines still rely on the traditional sources for pilot recruitment - the military and the industry. Neither of Canada's two national carriers presently have concrete plans to sponsor ab initio training in a similar manner to that which occurs in Europe.

Cabin Safety and Passenger Awareness

Socioeconomic factors may also be compromising the ability of the cabin crew to fulfil their regulatory responsibilities. Most passengers, if asked why there are flight attendants on aeroplanes, would answer **service**. The real reason for the regulatory requirement for trained cabin attendants, knowledgeable and skilled in emergency procedures, is **safety**. Company marketing has responded to customer expectations and demands in a highly competitive environment by offering the wide range of extras now on-board - newspapers, pillows, blankets, food, drinks, duty free and boutique sales, and child care and amusement facilities.

This may be perfectly safe in normal cruise at 40,000 feet. But what happens if the aircraft suddenly experiences severe clear air turbulence; or if an emergency descent, landing and evacuation is required? Direct safety implications exist because of serving carts blocking the aisles; "FOD" such as dishes, utensils and trays throughout the cabin; passengers impaired by alcohol impeding access to and operation of the emergency exits; and a cabin

crew in the "serving mode" trying to regain situational awareness and get back in the control loop. This is compounded by the lack of team work between cockpit and cabin crew. As the surviving flight attendant from the Air Ontario accident testified, the only time they get together is for dinner.

Competing service duties contribute to the problem of cabin attendants exempting themselves from the "fasten seat belt" sign. Often they are not strapped into their protected seats, not manning their assigned stations, nor are they necessarily capable of getting to them. They have even been known to open overhead compartments and start handing down passenger belongings while taxiing to the arrival gate. This invites injuries from falling objects or from flying objects if sudden braking is necessary, and sets a poor example for passengers.

Decision-Making Training

Training materials and courses to improve judgement and decision making skills are generally known by two names: pilot decision making (PDM) or aeronautical decision making (ADM) in the US; and cockpit resource management (CRM). PDM or ADM is aimed primarily at the single pilot operator while CRM and its affiliate, Line-Oriented Flight Training (LOFT), are designed for training multi-person crews as a team.

i. The Case for PDM

Following the 1977 report by Jensen & Benel, the FAA, Transport Canada, the French and Australian governments worked co-operatively for several years to produce and evaluate student and instructor aeronautical decision making manuals. Research was conducted in both Canada and United States to evaluate the effectiveness of judgement training. Despite certain methodological shortcomings, this research established that decision making as a skill, can be taught in the same manner as any skilled behaviour. Improvements ranged from 10% to 50% depending upon the training situation.

Methodological issues concern the construct validity and the use of unvalidated instruments (scales) to measure the five "hazardous thought patterns" or HTPs (which became known as "attitudes" in subsequent work). Initial identification of the five HTPs was based only on the informed opinions of experts (Berlin et al, 1982). Dr. Lewis Lester and various colleagues have conducted studies (e.g. 1984, 1986, 1987) to examine the construct validity; to establish base rates for different HTPs; to determine how HTPs are related to pilot personality; and whether HTPs and pilot personality are related to pilot involvement in dangerous aviation events. Results suggest that irrational decision making could be accounted for by reference to three HTPs: invulnerable, macho and impulsive with invulnerable being predominant. The authors also conclude that the HTPs and the global measure of irrational pilot judgement are related to personality and to the risk of involvement in dangerous aviation events (Lester & Connolly, 1987).

The FAA has developed three sets of training manuals (specific titles are listed in Appendix B) containing information on mental attitude assessment, stress management, cognitive processes, risk assessment and management, and crew coordination. The "Basic Pilot Series" consists of three manuals - student (and private), instructor, and helicopter. The "Professional Pilot Series" also consists of three manuals for the instrument pilot, commercial pilot and multi-person crews. The Air Ambulance series consists of four manuals written for air ambulance helicopter pilots, operators and hospital administrators.

The Aviation Safety Promotion branch of Transport Canada has been conducting PDM seminars with licensed pilots for approximately two years. Feedback is positive with respect to the concept. However, some people object to the forced-choice response format and to the scenarios, because they are written in the first person and because some of them suggest actions which are unsafe or unreasonable. These are some of the reasons why Transport Canada has not formally implemented the FAA manuals.

According to Dr. Alan Diehl, who managed the development of the first three generations of ADM manuals for the FAA, the student and instructor manuals could be redone to include such things as better illustrations (personal communications). He suggests research to develop: (1) a non-forced-choice hazardous attitude inventory; (2) methods of measuring judgements accurately during flight tests; and (3) methods of rehabilitating pilots who have been identified as having judgemental deficiencies. Denis Caravella, an FAA inspector in the West Chicago office, has been developing a standard for evaluating pilot judgement during flight tests (1989).

Both Diehl and Lester agree that a PDM action plan involves four steps: **training** - curriculum development for use in training pilots for various licences and ratings; **education** - development of non-regulatory material such as accident prevention seminars, advisory circulars, etc.; **certification** - regulatory procedures to assess candidate judgement at appropriate levels utilizing examinations, simulations or in-flight assessment; **rehabilitation** - remedial training in lieu of, or in conjunction with, licensing action for pilots involved in accidents, incidents, or violations.

ii. CRM Training Programs

Resource management is no different in the cockpit than in the office - it means effectively utilizing equipment, people and information to meet goals and objectives. Training programs address situational and sociopsychological factors that interact and influence crew performance. Some of the concepts in resource management training are: leadership, interpersonal communication, task distribution, priority setting, and effective monitoring.

During LOFT training, a crew completes a simulator trip during which they encounter a number of malfunctions resembling, as closely as possible, actual conditions that might be encountered, such as restricted visibility landings. During debriefing, the instructor acting as catalyst, encourages the crew to review individual and team performance and application of procedures to each situation using resource management principles.

The main commercial CRM training programs are: KHUFAC by KLM, a 5 day course consisting of 15 self-contained audio-visual modules of approximately 40 minutes each on different aspects of Human Factors; United Airlines 3 day course; and Continental Airlines 2 day course. Air Canada began a Canadianized version of the United course in March of this year and Canadian Airlines is incorporating the Wardair program entitled "The Right Track". The majority of CRM training is conducted with cockpit crews only.

5. RECOMMENDATIONS AND CONCLUSION

5.1 RECOMMENDATIONS

Develop A Transport Canada Human Factors Training Program

The objectives of Transport Canada Aviation Group (TCAG) are: "to ensure a safe and secure National Air Transportation System, and to attend to the efficient development and operation of the National Air Navigation System".

Human performance factors are identified in over 80% of aviation occurrences, but this figure applies equally to other modes of transportation. Transport Canada needs to commit necessary resources to develop a human factors program for training inspectors, air traffic controllers and other personnel responsible for safety in the various modes of transportation. The training program should be made available to others, such as the CASB, the military and the transportation industry.

Transport Canada should also develop and maintain a resource library and an up-to-date annotated inventory of ongoing research and development in the field of human factors.

Develop Decision Making Training Programs

Notwithstanding criticisms of the FAA manuals, evidence is accumulating attesting to the result. For example, Petroleum Helicopters Inc., the largest helicopter operator in the U.S., report that they have cut their accident rate in half over a two year period by voluntarily using the FAA Aeronautical Decision-Making Manual for Helicopter Pilots as part of their company training program (letter signed P.V. Hwoschinsky, Manager Rotorcraft Technology, FAA, dated October 2, 1989).

Transport Canada should introduce a series of PDM manuals for different audiences. In principle, these should address pilots at various levels (e.g. pilots in training for private, commercial or instrument, the recreational or sport pilot, the business pilot); as well as other personnel such as company management, maintenance and dispatch.

In addition, airlines and business operators should be encouraged to expand current CRM training to include flight attendants, company management and other personnel having direct responsibility for flight operations. This "crew" resource management training could take the form of structured courses or self-administered training manuals.

Finally, CRM courses designed for conventional cockpits need to be modified for glass cockpits. Earl Wiener refers to advanced technology aircraft as "devices with high authority and opportunity for error" (1988).

Improve Cabin Safety & Passenger Awareness

The cabin crew would be much better prepared to handle any in-flight situation if routine operational briefing were given by the cockpit crew, for example, the general conditions expected on approach, type of manoeuvring required and landing planned.

One method of reducing the competing demands on cabin attendants is to educate those with whom they interact - the company, the flight crew, and especially the passengers. Most passengers take no interest in, nor responsibility for, their own safety or the safety of others. They ignore the mandatory pre-flight safety briefings and don't read the safety features card. An old cliché states:

> tell me and I will forget
> show me and I will remember
> involve me and I will understand

Organizations such as the Air Transport Association of Canada, through their affiliates, could promote passenger awareness; major air carriers could offer simulated evacuation training; and the routine operational cabin briefings recommended above would also benefit the passengers - an informed person is less likely to panic.

Revise Regulatory Procedures

For the most part, regulatory inspectors can identify companies that are barely meeting standards. To help prevent operators from taking shortcuts with safety or maintenance, procedures for approving nominees for operational positions such as chief pilot, should go beyond the "paper trail" and should consider the person's management skills and whether the person will be given the authority to do the job. The list of mandatory operational personnel should be expanded to include a safety officer.

Specialists responsible for approval and certification of aircraft designs, modifications or components need human factors expertise to be available in order to assess the influence of man in the system in the operational environment.

5.2 OTHER RESEARCH AND DEVELOPMENT INITIATIVES

Information Transfer/ Pilot-Controller Interface

The communication breakdown problem identified in the CASB study has also been identified as a major problem in the US from analysis of ASRS data. As a result, the Air Transport Association (ATA) Human Factors Task Force in conjunction with government and industry has included information transfer methods as one of the nine elements in their "National Plan to Enhance Aviation Safety Through Human Factors Improvements" (April, 1989). They state that the information requirements of pilots and controllers need to be specified and methods developed for transferring, managing and integrating this information in ways that reduce the chance of human error.

Data Collection Methods

Accident statistics do not contain normative non-accident data. Better methods of collecting data from all transportation occurrences need to be developed. The Confidential Aviation Safety Reporting System (CASRP) initiated by the CASB in 1985 has not been widely utilized.

Selection, Training, Evaluation

In all probability, airline ab initio training will eventually become a reality in Canada. Research should be initiated to develop and evaluate "start from scratch" pilot selection and training criteria. Parallel research should be initiated with respect to selection and training of air traffic controllers. Also, training programs such as PDM and CRM must be subjected to comprehensive research and evaluation before implementation of any regulatory standards for personnel licensing or certification.

Unique Canadian Operations

The CASB study points to the need to conduct research into the effects on human performance of factors such as 24 hour day/night in the "land of the midnight sun". Also, variable hours of daylight and seasonal business cycles may contribute to pilots and other company personal exceeding safe limits.

Effect of Circadian Rhythms Within Air Traffic Services

The CASB study of ATS identified a problem of fatigue and stress resulting from shift cycles. Some of this may be self-inflicted by choosing to work excessive overtime, but some may be the result of regular shift cycles. Research should be conducted to establish the relationship between shift work schedules and fatigue/stress.

5.3 CONCLUSION

In this paper, I have attempted to give the reader an appreciation for the role of human performance in the aviation system. Awareness is the first step toward understanding and managing the problem.

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MAN-MACHINE-ENVIRONMENT FACTORS

The Human

Aviation Physiology

fatigue
hypoxia/hyperventilation
alcohol/drugs/smoking
anaesthetics
decompression
"the bends
blood donations
blackout/red-out
sleep disturbance
circadian rhythms
disorientation/illusions
vertigo
phobias (space/height)
pregnancy
ageing

Aviation Psychology:

skills - perceptual
cognitive
decisional
workload
stress
personality
attitudes
motivation
situational awareness
leadership
team work
resource management
judgement

The Machine

Hardware

cockpit/cabin design
controls and displays (e.g. design, movement, size, scales, colour, illumination)
alerting/warning systems
personal comfort (seat adjustment/control, illumination)
cockpit visibility
motor workload

Software

rules, regulations, laws, habits
procedures, customs, practices
manual/checklist layout
symbology, computer programs
effects of automation (overload/underload, complacency/boredom, staying in the control loop/situational awareness)
voice interactive systems synthesized speech

THE ENVIRONMENT

Internal

temperature
pressure
humidity
noise
lighting
vibration
radiation
pollutants/contaminants

External

terrain
weather
other air traffic
day/night effects
take off & landing conditions

Socioeconomic

legal/regulatory
company structure/
economic climate
employer/employee relations/
unions
family relationships
peer groups/professionalism
crew experience

THE OTHER PEOPLE

Communications

flight deck crew
cabin crew
maintenance/engineers
company management
flight dispatch/watch
air traffic services
passengers

Problem Solving

Decision-making

Group Dynamics

Crew Management

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